Next Generation Space Telescope

NGST

A NASA Origins Mission

Planetary Science with the Next Generation Space Telescope (NGST)

American Astronautical Society

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November 13, 2001

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-- Outline --

- NGST at a glance
- Instruments and Science Goals
- Planetary Science
- Organization and Schedules
- Technology development

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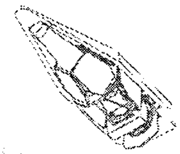
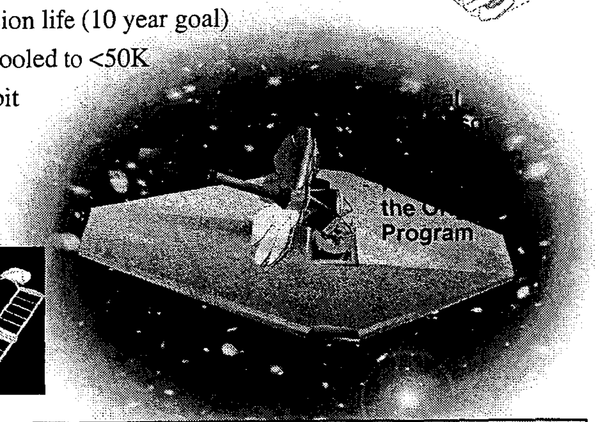
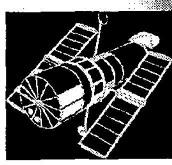
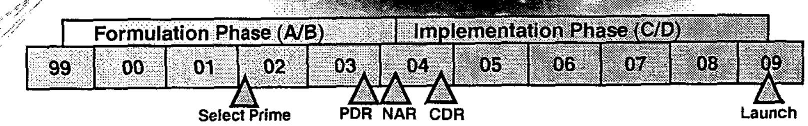
NGST at a Glance



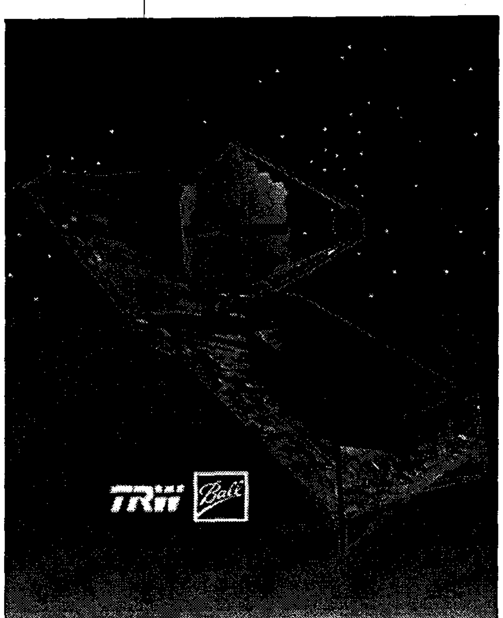
- 6-meter class deployable primary mirror
- 0.6-28 μm wavelength range
- 5 year mission life (10 year goal)
- Passively cooled to <50K
- L2 halo orbit

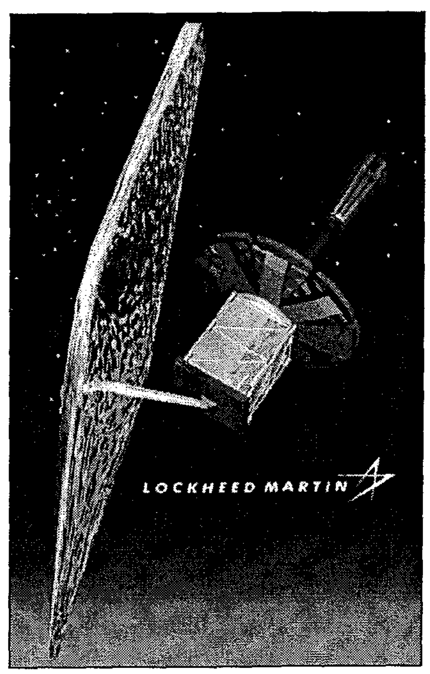




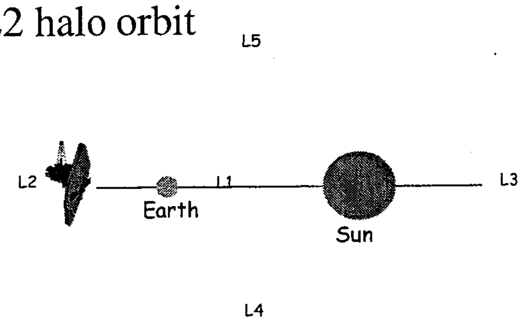


NGST Concepts





NGST at L2 halo orbit



- **Single sunshield protects from Earth and Sun**
- **8-16 hour visibility from single ground station**
- **Simple operations compared to HST**
- **0.01 AU away, but not serviceable by astronauts**
- **Halo orbit around L2 avoids Earth shadow**
- **Unstable orbit requires ~ 3 m/sec/year corrections**

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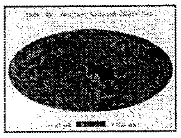
ASWG recommended Instrument Suite

- 4′ x 4′ NIR Camera
  - Nyquist sampled at 2 μm, 0.6-5 μm, *R*~100 grism mode
  - Deep imaging of early universe, history of element formation
  - Star formation and faint objects nearby
- 3′ x 3′ NIR *R*~1000 Multi-Object Spectrograph
  - Simultaneous source spectra (≥ 100), 1-5 μm
  - Redshifts, chemistry
- 2′ x 2′ Mid IR Camera/*R*~1500 Spectrograph
  - Nyquist sampled at ~10 μm, 5-28 μm, grisms & slit
  - Star formation and planet studies

Top NGST Goal - Find the First Light after the Big Bang

[illegible] as seen by COBE



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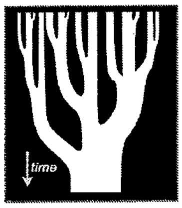
Galaxy assembly



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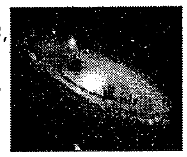
Galaxies, stars, planets, life



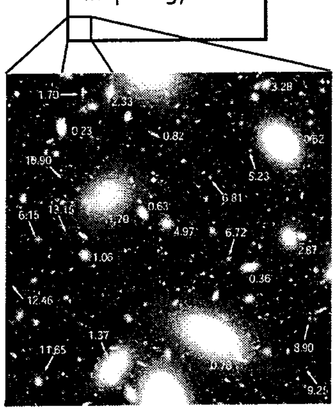
- How and from what were galaxies assembled?
- What is the history of star birth, heavy element production, and the enrichment of the intergalactic material?
- How were giant black holes created and what is their role in the universe?
- When could planets first form?

NGST Deep Imaging: 0.5–10 μm

ASWG: Simon Lilly

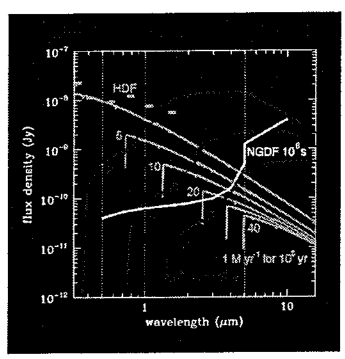
4'x4' deep survey field

5000 galaxies to AB ~ 28,
10^5 galaxies to AB ~ 34
photometry, morphology & z's



Depth: AB ~ 34 in 10^6 s
Redshifts: Lyman α to $z = 40$ (?)
4000 Å to $z = 10$

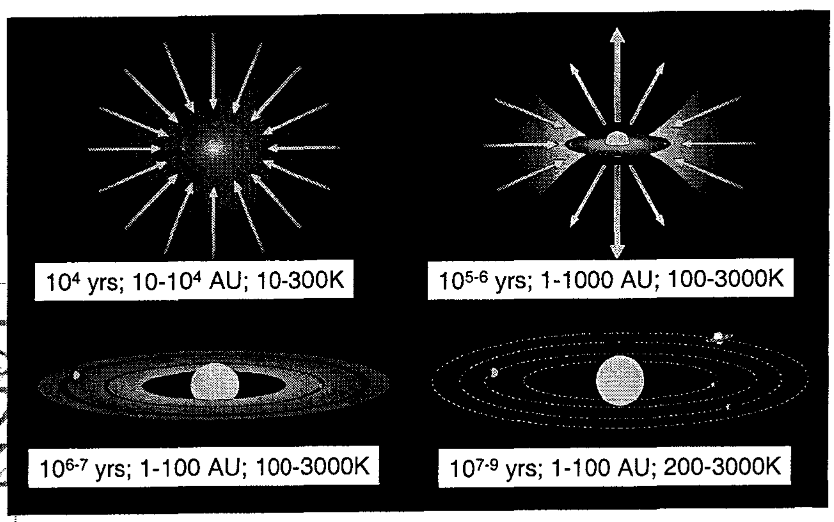
NGST will detect 1 $M_\odot$ yr^{-1} for 10^6 yrs to $z \geq 20$ and 10^8 $M_\odot$ at 1 Gyr to $z \geq 10$ (conservatively assuming $\Omega = 0.2$)



Origins of Planets and Life - Primary NGST Science

- History of metal abundances as raw materials over age of Universe - when could life first form?
- Direct view of protoplanetary and planetary debris disks
  - Temperature, density, chemistry, orbital resonances with planets
  - Relation to formation of binary stars
  - Organic chemistry - astrobiology
- Direct view of planetary-mass objects
  - Easy for objects separated from bright stars
  - Difficult and unlikely for old planets in orbit
  - Scientific and technical precursor for TPF
- Comparative planetology - Solar System objects versus observed disks, "loose planets"

The formation of single, isolated stars



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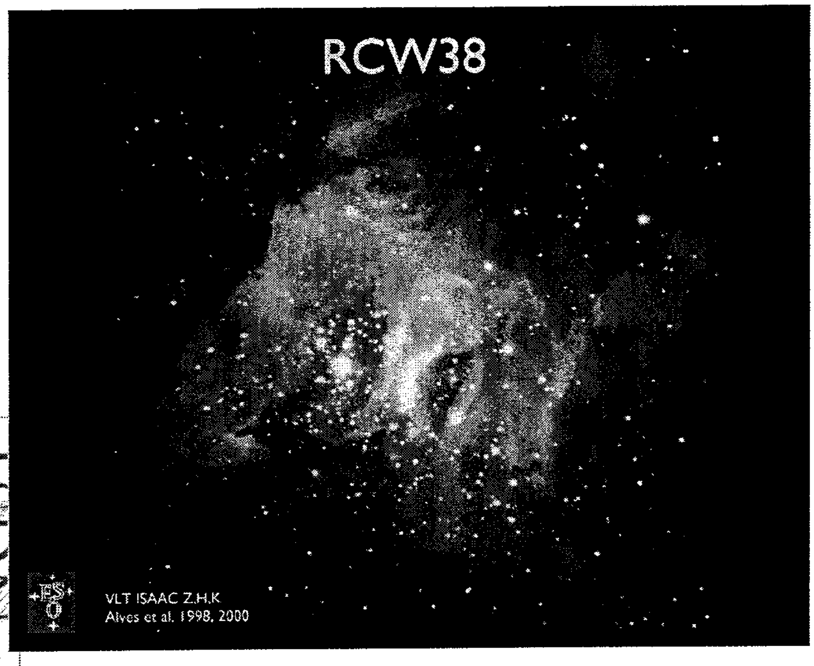

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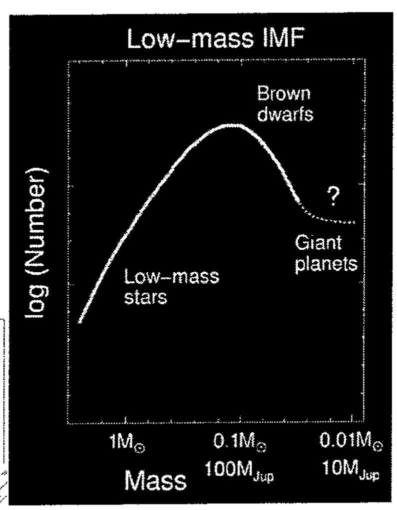
Initial mass function - Low mass objects



Study IMF as function of environment (cluster density, metallicity, galactic location):

- Ratio of high- to low-mass stars
- Location of turnover
- Presence of planets

Assuming 1 Myr old and A_V=10, K_{AB}=26.5 gives:

- 1M_{Jup} at 2kpc
- 0.1M_{Sun} at 55kpc (LMC)

Connection to extragalactic and primordial star formation

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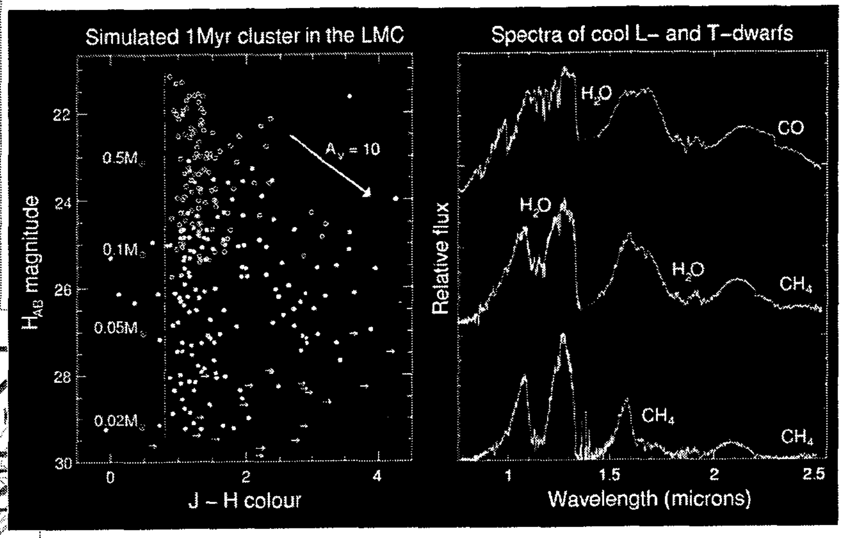
Deep IR imaging & spectroscopy …



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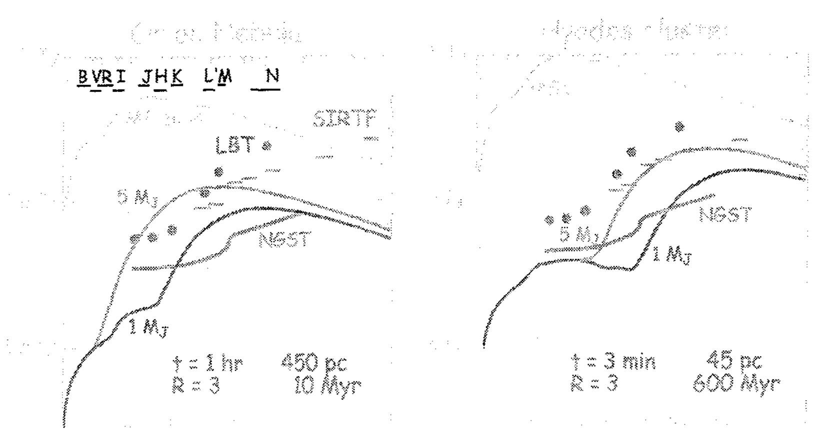
Nearby Low-Mass Objects are easy to see

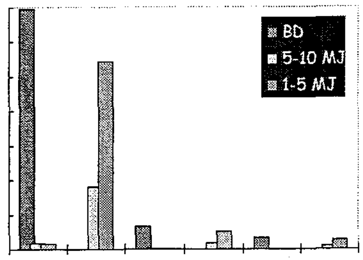


after Saumon *et al.* 1996, *Ap.J.*, **460**, 993.

Surveys for Young Planets

Region	D (pc)	R_{abs} (pc)	Myr	l (mm)	T (hr)	#FOV	Stars	BD	5-10 M_J	1-5 M_J
Orion	450	1.2	1	4	16	16	1600	1389		33
Orion: flat										1087
Pleiades	150	1.7	120	10	50	500	150	130		3
Pleiades: fl										102
Hyades	45	0.6	600	20	50	1000	75	65		1
Hyades: fl										51

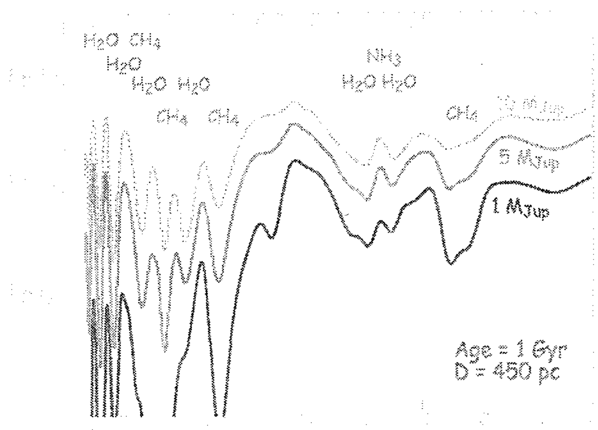
		10^6 yr		10^9 yr
M/M_{Jup}	l (mm)	D(pc)	l (mm)	D(pc)
1	5	2500	20	
2	5	3500	10	
5	5	8900	10	
10	5	32000	5	



cluster input from Michael Meyer, MPIA

Spectra of Giant Planets

from Adam Burrows 1997



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Coronagraphic Possibilities for NGST

- Simple blocker in image plane
- High order deformable mirror for wavefront correction in instrument
  - Subject of detailed study by John Trauger for NGST
  - Not given priority by ASWG
- Aperture masks (graded Lyot, phase masks) in pupil plane filter wheel
- Rotation Shearing Interferometer
- Could be proposed as a feature of the Near IR Camera (NIRCAM) under the NGST AO
- Could be proposed as a feature of the Mid IR Instrument in NASA/JPL - ESA partnership

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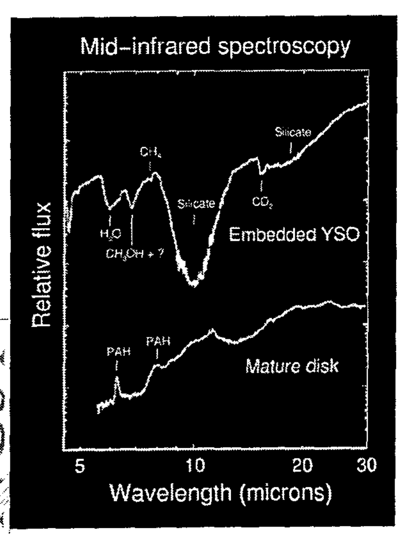
From disks to planetary systems



High-resolution, sensitive near- and mid-IR imaging:

- Structure (radial/vertical profiles, gaps, warps)
- Environmental influences
- Associated outflows

Sensitive spectroscopy:

- Gas dissipation
- Dust grain agglomeration
- Organic chemistry
- Disk dynamics

Large samples to trace disk evolution → gas giants and terrestrial analogues

Evolution of circumstellar disks

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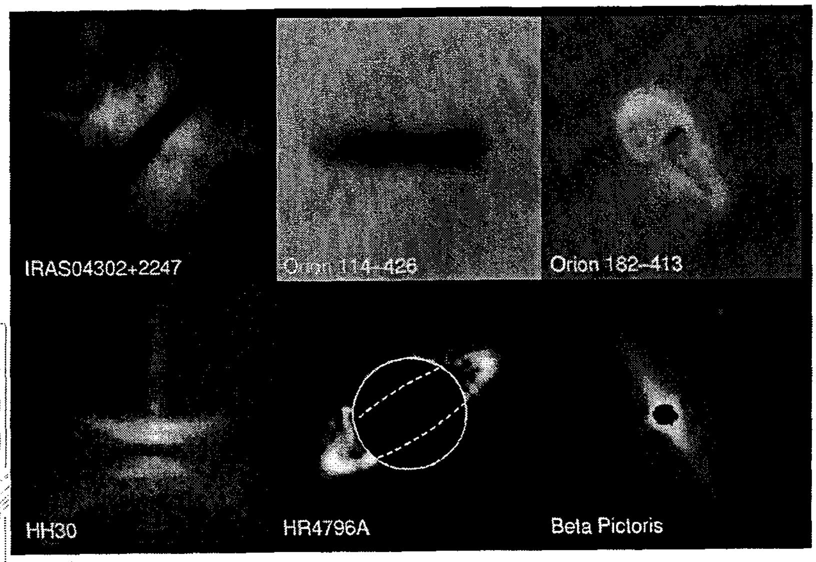


11-13-01 Serabyn Mather.ppt

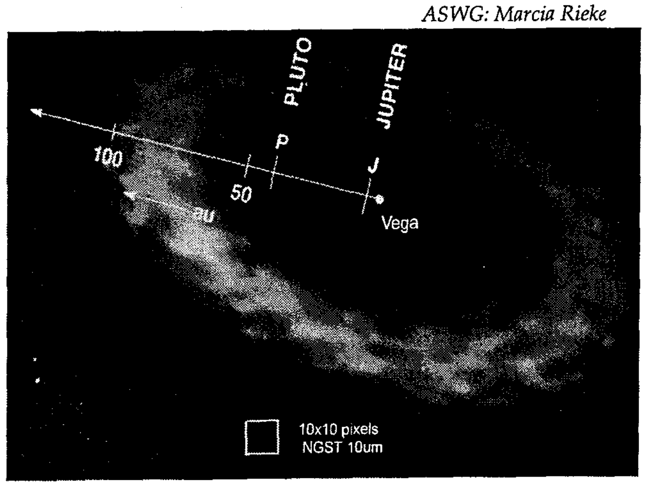
Evolution of Planetary Systems

ASWG: Marcia Rieke

Vega Disk Detection

λ (μm)	Flux* (μJy)	Contrast Star/Disk
11μm	2.4	1.5×10^{7}
22μm	400	2×10^{4}
33μm	1300	3×10^{3}

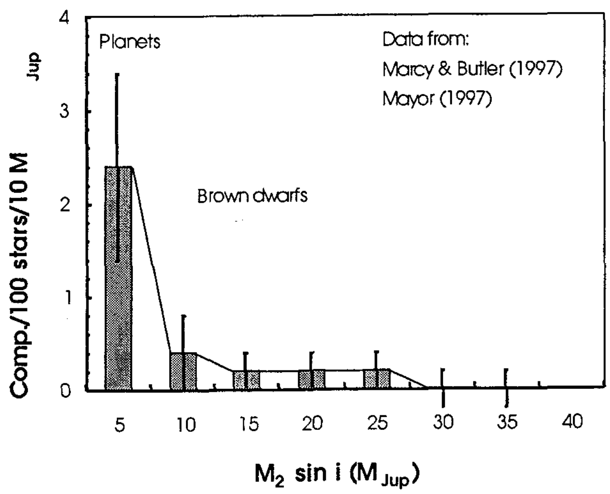
Reflected & emitted light detected with a simple coronograph.



NGST resolution at 24μm = 5 AU at Vega, > 10 pixels across the inner hole

**per Airy disk*

Low-mass Companions are common



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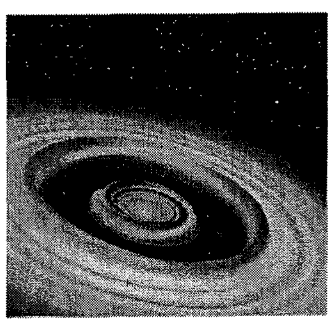
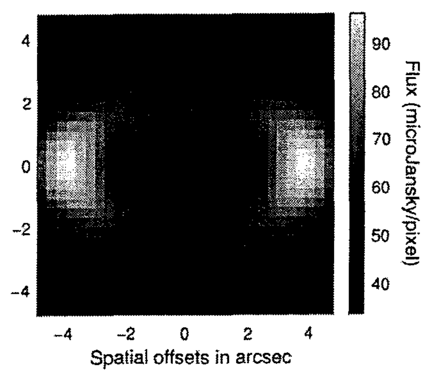
Planet-induced gaps in disks

Simulation of gap formation in a circumstellar disk by a giant planet



Height and colour of disk indicate gas density

Simulated 3 hour NGST image of 55 Cancri at 20μm



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Extrasolar Planets - Direct Observation?

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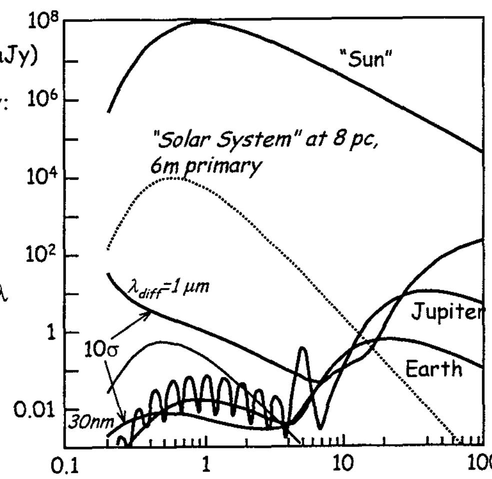
From Angel & Woolf 1998, in *Science with the NGST*, ASP, **133**, 172

- Control of primary only:
  - Jupiter at $10 < \lambda < 20\ \mu m$

- Active wavefront correction to 30 nm rms - Direct detection of Jupiter $\lambda > 0.4\ \mu m$

Not a baseline program, but a natural upgrade issue for future missions such as TPF or an NNGST.



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Solar System Observations

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- Kuiper belt objects
  - NGST advantage: sensitivity
  - Moving object tracking strongly recommended by ISWG (Interim Science Working Group), depends on capabilities of Canadian Fine Guidance Sensor
  - Orbit distribution, formation, temperature, mineralogy
- Comets
  - NGST advantage: full wavelength coverage for modest resolution spectroscopy
- Planets, asteroids, and satellites
  - NGST advantage: wide wavelength coverage
  - Can't point closer than about 85° from Sun

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International Partnership Concept

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- ESA ~$200M (FY96) value of effort, gains 15% observing time on HST and NGST; ESA has approved funding subject to successful detailed plan
- CSA ~$50M (FY96) value of effort, gains 5 observing time on NGST
- Initial goal 50-50 split of instrument/non-instrument contributions
- Exploring ESA contribution to spacecraft bus, based on Herschel (FIRST)/Planck bus contract to Alcatel
- CSA and ESA would fund staff at STScI

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Instrument Partnership Plan

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- ° ° NASA to provide shared instrument services (electronics, thermal, data system, ...) and integration and test
- NASA AO to provide NIRCAM
- ESA to provide NIRSPEC, based on US detectors and multiobject selector
- NASA/ESA/member nations and NASA/JPL to develop detailed partnership plan for Mid IR instrument. US to provide detectors and their electronics.
- CSA to provide separate fine guidance sensor, and contributions to NIRCAM

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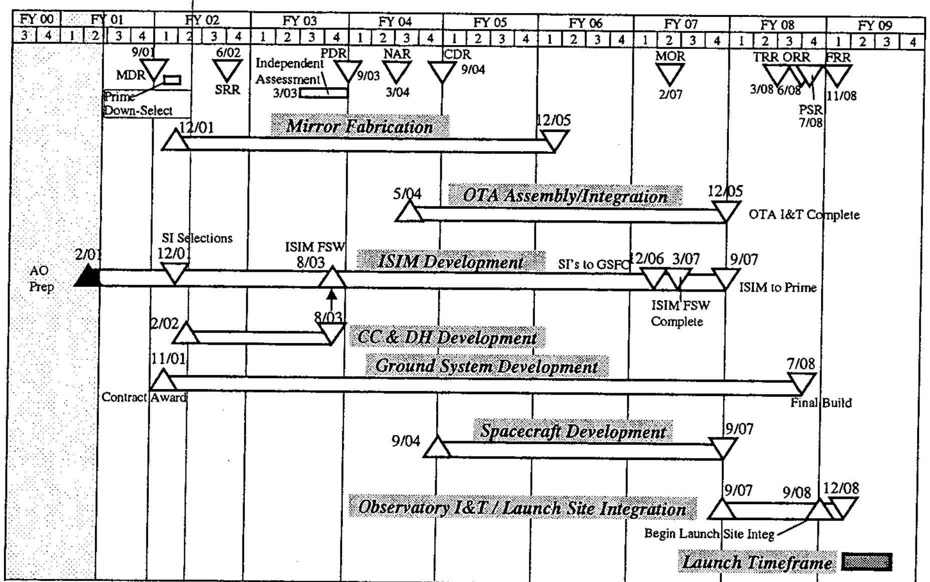
NGST Top Level Observatory Schedule



STATUS AS OF: 03/09/01

Getting a Good Mirror, Adjusting it to fit

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- Promising Mirror Technologies:
  - Beryllium,
  - Glass sandwich,
  - Glass on fiber supports,
  - Glass meniscus on adjustable points
- Cold testing in progress
- Cryo-null figuring possible - figure warm, measure cold, warm up, figure in the corrections
- Actuators adjust radius of curvature, modest number of error modes
- Phase error sensing by image analysis, in and out of focus

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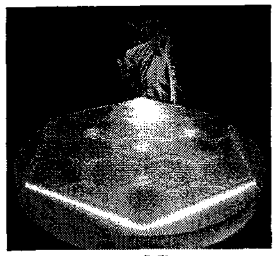
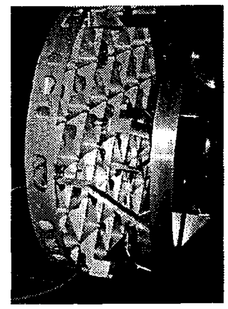
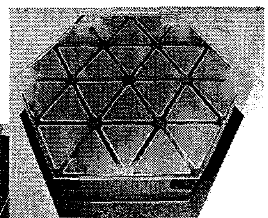
NGST Mirror Technology Development

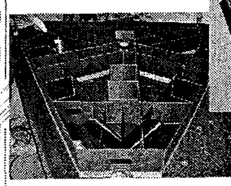


Kodak Mirror

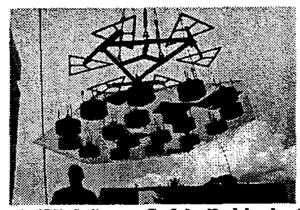


SBMD Mirror





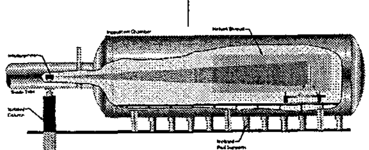
COI Mirror



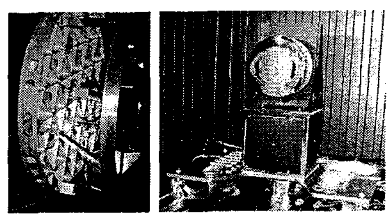
NMSD Mirror Safely Deblocked

NGST

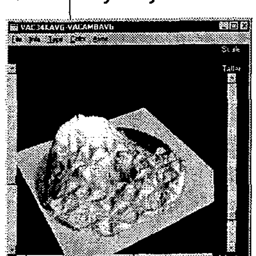
Cryo Testing of SBMD at MSFC



Cryo Test Facility Layout



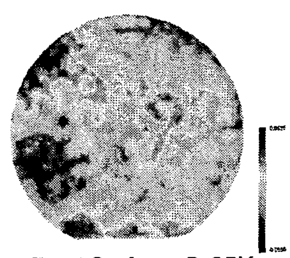
SBMD (9.8 kg/m²) Mounted in Chamber



Cryo Deformation

Surface error: 34K - 288K
(571 nm p-v; 63 nm rms)

Cryo Figure

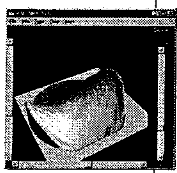


Final Surface @ 35K

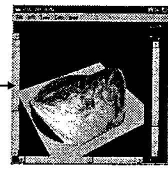
(17 nm rms)
Gravity Corrected

UAH

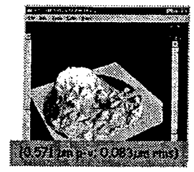
Validation of SBMD Cryo-Null Figuring



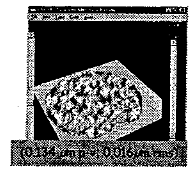
Shack-Hartmann test of SBMD in XRCF at **ambient** temperature in vacuum. The anticipated astigmatism comes from the self-weight deflection of the assembly held with optical axis horizontal.



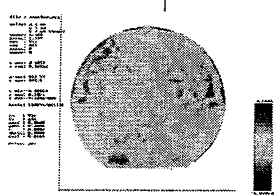
Shack-Hartmann test of SBMD in XRCF at **34K** . Print-through of the lightweighted web structure is clearly visible as the mirror distorts at cryogenic temperatures.



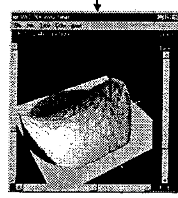
Difference between cryo and ambient surface figures. The **cryomap** to be applied to the existing surface is generated from this data.



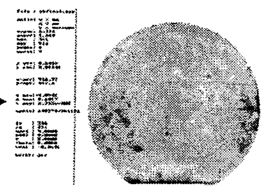
High spatial frequency residual error left over after subtracting best-fit 42 term Zernike polynomials from cryomap.



Ambient temperature measurement of SBMD with cryomap applied, ready for final test.

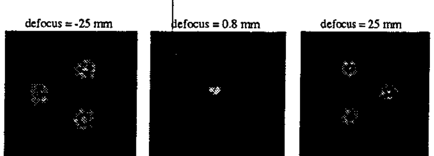


At 38K, web print-through and center dimple are significantly reduced compared to cryo map at 34K prior to cryofiguring.

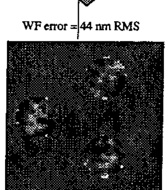


Final surface of SBMD at cryogenic temperatures, with gravity effects removed by averaging of multiple rotations.

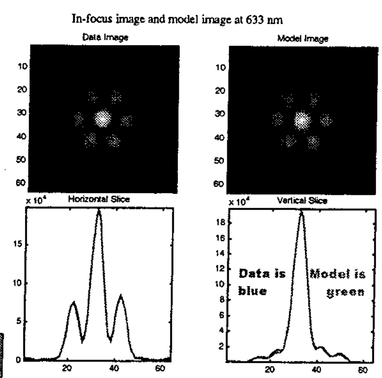
WCT- 2 Segment Mirror Phasing



Typical images used for WF sensing and control

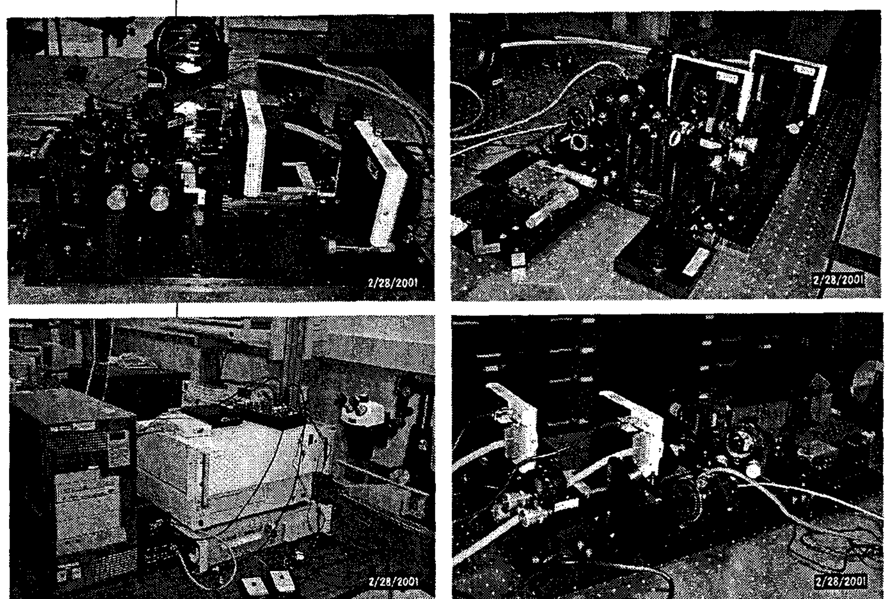


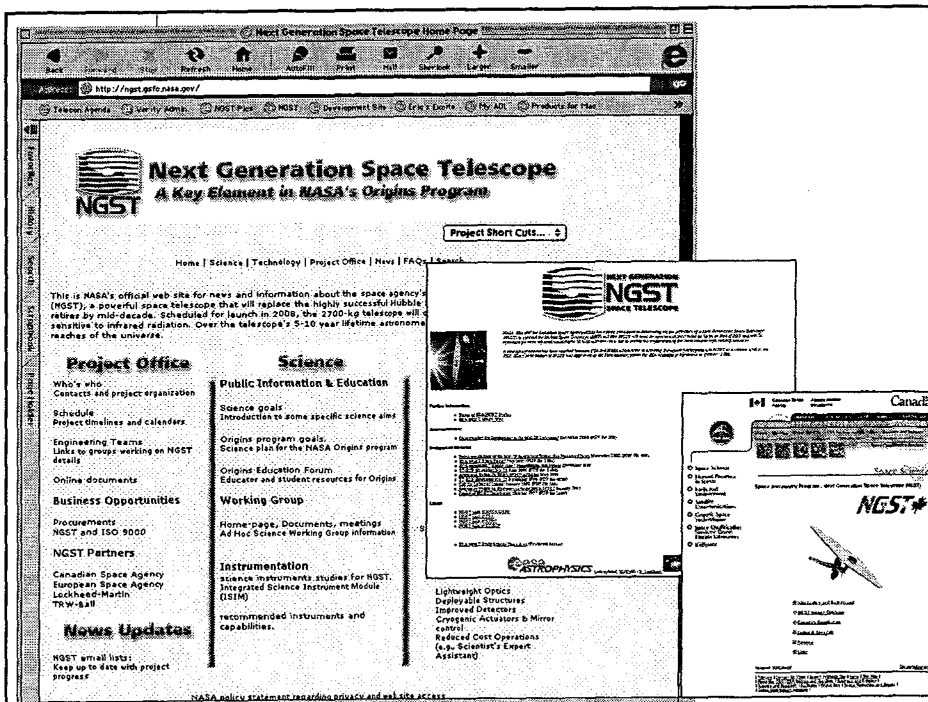
Retrieved WF after control

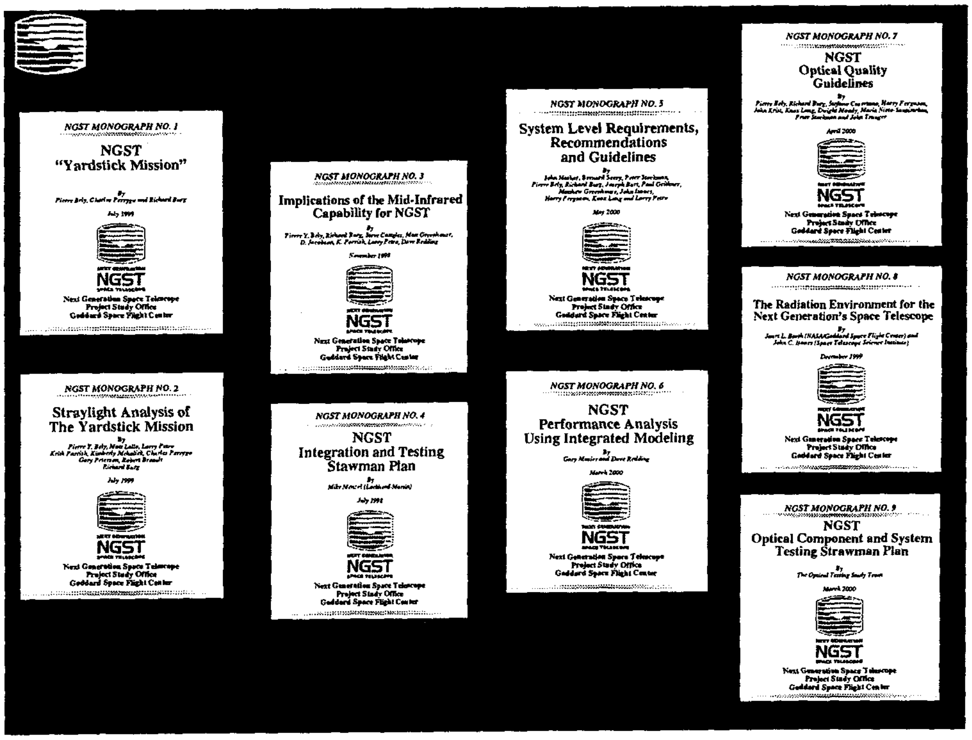


In-focus images prove excellent broad-band phasing

JPL Phase Retrieval Camera







NGST MONOGRAPH NO. 1
NGST
"Yardstick Mission"
NGST MONOGRAPH NO. 2
Straylight Analysis of The Yardstick Mission
NGST MONOGRAPH NO. 3
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